DOCUMENT RESUME

ED 240 703 EA 016 469

AUTHOR	Moursund, David
TITLE	Precollege Computer Literacy: A Personal Computing Approach. Second Edition.
INSTITUTION	International Council for Computers in Education, Eugene, Oreg.
PUB DATE	Apr 83
NOTE	33p.; This booklet is an updated and expanded version of a paper, "Personal Computing for Elementary and Secondary School Students," presented at a computer literacy conference organized by the Human Resources Research Organization and the Minnesota Educational Computing Consortium (Reston, VA, 1980).
AVAILABLE FROM	Publications, International Council for Computers in Education, 1787 Agate Street, University of Oregon, Eugene, OR 97403 ($1.50 prepaid; quantity discounts; on non-prepaid orders, add $2.50 postage and handling).
PUB TYPE	Information Analyses (070) -- Reports - Evaluative/Feasibility (142)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Computer Assisted Instruction; *Computer Literacy; *Computer Oriented Programs; *Computers; Curriculum Development; Educational Technology; Elementary Secondary Education; *Futures (of Society); *Programing; Student Teacher Relationship; Technological Advancement

ABSTRACT

Intended for elementary and secondary teachers and curriculum specialists, this booklet discusses and defines computer literacy as a functional knowledge of computers and their effects on students and the rest of society. It analyzes personal computing and the aspects of computers that have direct impact on students. Outlining computer-assisted learning (CAL), the author delineates two types: tutor mode CAL (the computer imparts knowledge to the student) and tutee mode CAL (the student directs interaction with the computer). Discussing the use of computers as an aid to problem solving in the classroom, the author predicts it will substantially change parts of the curriculum. The discipline of computer and information science is a new and important discipline, and high schools may need to provide such courses as part of computer literacy. Describing entertainment uses for the computer, the author shows there is no clear dividing line between entertainment and education. Students understanding the computer's potential for change are better prepared to plan their future. The booklet includes a glossary of computer terms. (MD)

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PRECOLLEGE COMPUTER LITERACY: A PERSONAL COMPUTING APPROACH

David Moursund

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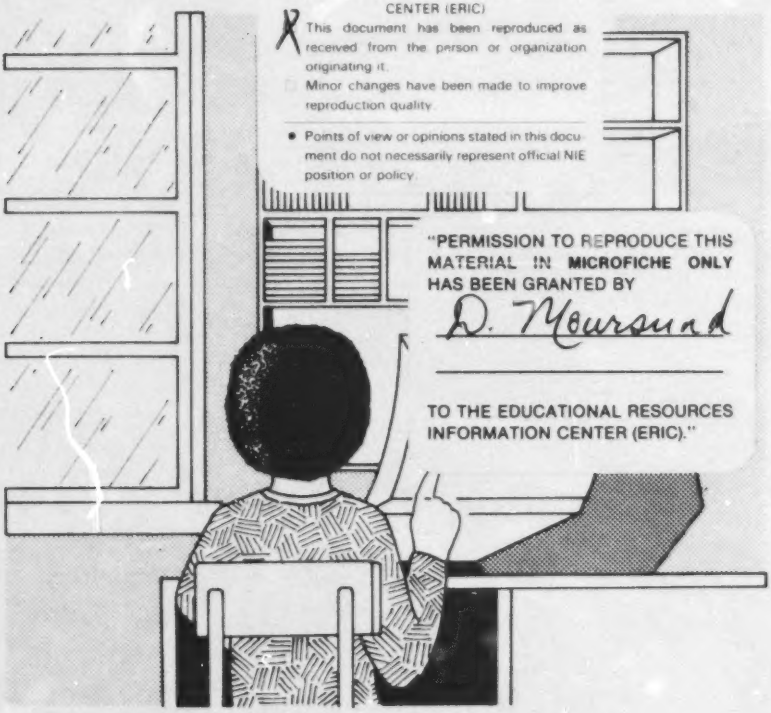

EA 016 469

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Second Edition April 1983

Price $1.50 U.S.

David Moursund, the author of this book, has been teaching and writing in the field of computers in education for the past sixteen years. He is a professor at the University of Oregon, holding appointments in the Department of Computer and Information Science and in the Department of Curriculum and Instruction.

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- Author or co-author of ten books and numerous articles.
- Chairman of the University of Oregon's Computer Science Department, 1969-1975.
- Chairman of the Association for Computing Machinery's Elementary and Secondary Schools Subcommittee, 1978-1982.
- President of the International Council for Computers in Education and Editor-in-Chief of *The Computing Teacher*.

This book is published by the International Council for Computers in Education, a non-profit, tax-exempt professional organization. ICCE is dedicated to improving educational uses of computers and to helping both students and teachers become more computer literate. ICCE publishes *The Computing Teacher*, a journal for teachers and for teachers of teachers. It also publishes over ten booklets of interest to educators.

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ABSTRACT

It is generally agreed that all students should become computer literate, but no definition of computer literacy has gained widespread acceptance. This booklet defines computer literacy in a manner that can guide educators as they work to implement universal computer literacy through precollege education.

This booklet is an updated and expanded version of a paper, "Personal Computing for Elementary and Secondary School Students," prepared by David Moursund for a computer literacy conference held in December 1980 in Reston, Virginia. The conference was organized by the Human Resources Research Organization and the Minnesota Educational Computing Consortium. The purpose of the conference was to help participants gain an increased understanding of the meaning of computer literacy and what can be done to help students become computer literate.

This booklet is intended for curriculum specialists, elementary and secondary school teachers, media specialists, teachers of teachers and others concerned with curriculum in precollege education. It defines and discusses computer literacy for elementary and secondary school students. The approach is via an analysis of personal computing and the aspects of computers that can have a direct impact on students. Students can be personally involved with computers through computer assisted learning, computer assisted problem solving, the study of computer and information science and through the use of computers for entertainment. Students can learn how computers are affecting the world of business, government and industry—and thus, how computers will be part of their future. Each of these aspects of personal computing contributes to the definition of a set of goals for computer literacy in elementary and secondary schools. The resulting overall goal is for a working knowledge of computers—that is, knowledge that facilitates the everyday use of computers by students. This knowledge lays a firm foundation for future learning about computers and for coping with the inevitable changes that will occur in this technology.

PERSONAL COMPUTING (noun phrase) Easy to use, readily available, inexpensive access to electronic digital computers for personal use. The term gained prominence in the late 1970s with the advent and rapid proliferation of microcomputers. Since then prices have continued to decrease, while the quality and capability of microcomputers have increased substantially. The first commercially available handheld computer, introduced in 1980, and a variety of briefcase-sized computers introduced since then have lent credence to the idea of people having easy and nearly unlimited access to computers for everyday, personal use.

HISTORICAL OVERVIEW (TECHNICAL)

The history of computers can be viewed in terms of progress toward making computer systems more readily available and easier to use. The first stage was to make computers available—to invent the fundamental ideas and to build the first machines. During the late 1930s and early 1940s, substantial progress occurred in England, Germany and the United States. The first general-purpose electronic digital computer built in the United States was the ENIAC, which became operational in December, 1945.

The ENIAC and other early vacuum tube computers were difficult to use. The development of assembly languages and assemblers helped. But still, each computer required a team of electrical engineers and technicians to insure operation, and the machines were not very reliable. Computer memories were quite small and internal instruction sets (machine languages) were restrictive. The process of preparing programs and getting them into machine usable form was exacting and time-consuming.

By 1951, however, many of the initial problems had been overcome and the UNIVAC I, the first commercially produced computer, became available. Over one hundred of these machines were eventually produced and sold, evidence of a rapidly expanding market for computers. However, the UNIVAC I and other computers of the 1950s used vacuum tubes. Maintenance and reliability remained major problems, along with the size of both primary and secondary storage and a shortage of good software and programmers.

During the 1950s, high level programming languages such as FORTRAN, COBOL and ALGOL were defined and implemented. Transistors became readily available, as did primary memory which made use of tiny iron cores. The second generation of computers that emerged in the early 1960s represented tremendous progress toward making computers more readily available, reliable and convenient to use. Some of these machines remained in service for 15-20 years.

Rapid technological progress in both hardware and software continued. Timeshared computing, especially interactive BASIC, provided a new standard of personalization in computing. Even more importantly, however,

the 1960s saw the development of a process to manufacture a single (integrated) circuit containing a number of interconnected transistors and related components. Component density rapidly mounted from tens to hundreds to thousands on a single silicon chip. The cost per active component dropped rapidly, and reliability increased.

Large scale integrated circuitry helped define the term "third generation" of computers in the mid 1960s. Tens of thousands of computers were manufactured and installed. Minicomputers were priced so that an individual researcher or research project could own one. Computers became an everyday tool for hundreds of thousands of people. Since then, progress has been relatively smooth and continual. Thus, there is no agreed on definition of fourth or fifth generation computers.

The era of personal computing began with the introduction of microcomputers in the latter half of the 1970s. Suddenly it became possible for an individual to own a computer for use at home, in the office or in the classroom. The cost of teaching using computers rapidly dropped by almost an order of magnitude. Students, even in the elementary grades, could have hands-on experience with computers.

In 1980, a battery powered computer, the size of a handheld calculator and programmable in BASIC, became commercially available at a retail price of about $250. By 1981 this machine was being discounted to $200. In 1980 and 1981 several companies introduced easily portable briefcase-sized computers. Their advertising campaigns stressed the idea that these computers could be taken on business trips, thus having them available for use at all times.

In 1981, Hewlett-Packard announced a 450,000 transistor chip. This single chip contains more circuitry than many of the large scale computers of the early 1960s. In 1982, Casio began selling an ordinary-sized wristwatch which contains a 1,711 word Spanish-to-English and English-to-Spanish dictionary as well as the ordinary wristwatch functions. December of 1982 saw the sale of many battery-powered, handheld electronic games as well as tens of thousands of computers. Estimates are that two million personal computers were purchased for home use in the United States in 1982, and that four million more will be purchased in 1983.

These advances have opened up the possibility of personal computing for the general population. Computer manufacturers could produce a microcomputer for every home, office and student desk at school. These individual units could be connected to each other and to larger computers through our telephone systems and our cable television systems. Not only is this possible, but it is quite likely to occur over the next 10-20 years.

HISTORICAL OVERVIEW (EDUCATIONAL)

A number of the early computers were built at university campuses and were immediately used for both research and instruction. But first generation computers were relatively expensive, so their use in education was limited.

The 1960s saw a rapid proliferation of computers in education, especially in colleges and universities. Hundreds of computer science and data processing degree programs were started. Computers were easy enough to use so that college undergraduates could take a few computer courses and emerge from college with well paying jobs as computer programmers or system analysts.

By the early 1960s a few secondary schools had computer access and a few teacher training opportunitites were available via evening, weekend or summer courses. Later in that decade and in the first half of the 1970s, the National Science Foundation funded a number of inservice and summer institute computer courses for secondary school teachers. Most participants were mathematics or science teachers. Typical institute courses covered programming in FORTRAN or in BASIC, and some computer-oriented mathematics. The impact upon precollege education at that time was minimal, since few secondary schools had more than a modest computer facility available. In recent years, however, many of these early computer institute participants have emerged as computer education leaders in their schools and school districts.

Since the late 1950s, people have worked to develop computer assisted learning systems. Stanford University professor Patrick Suppes received substantial federal funding during the mid 1960s to develop and test drill and practice materials in elementary school arithmetic and language arts.[3] Many of today's drill and practice materials can be traced back to the pioneering efforts of Suppes' group. Computer assisted learning has become a major application of computers in precollege education.

The Colorado Project[1] was a leading example of early efforts to make significant use of computers in high school mathematics. This second year high school algebra and trigonometry course was developed in the late 1960s. Students studied BASIC during the first few weeks of the course and throughout the remainder of the course were expected to write short programs as part of their efforts to learn algebra and trigonometry. The popularity of this course probably peaked in the mid 1970s and has since declined. For example, at one time nearly 10% of the high schools in Oregon offered at least one section of the course. But overall, few teachers felt qualified to teach the course, and the inclusion of computer programming into an already crowded course added to the difficulty of teaching it.

Despite such curriculum problems, instructional use of compuers increased steadily through the mid 1970s and then accelerated as microcomputers became available. By the end of 1982 there were an estimated

200,000 microcomputers in use in precollege education in the United States—about one for every 250 students.

These microcomputers were not evenly distributed. In Eugene, Oregon (the author's home town) for example, there was one microcomputer for every 90 students. Every junior high school and high school in this town of 100,000 population offered computer programming courses and made some use of computers in non-computer courses. Several elementary schools were experimenting with computers, using both the BASIC and Logo languages.

An added impetus for computer science instruction in high school is provided by the Advanced Placement Test (students can earn up to a year of college computer science credit) that will become available in the spring of 1984. Roughly one-third of United States high schools offer an advanced placement-oriented calculus class. Most of these schools and many others may eventually want to prepare students for the advanced placement computer science course.

HISTORICAL OVERVIEW (COMPUTER LITERACY)

The idea of computer literacy for the general student population probably first emerged in the late 1960s. Leaders in the field of computer and information science began to suggest that all people needed to know something about computers. The Conference Board of the Mathematical Sciences recommended universal computer literacy in its 1972 report,[2] suggesting that this could be achieved via a junior high school computer literacy course. Although its request to the National Science Foundation for funding to develop such a course was denied, many individual teachers began to offer computer literacy units or entire courses, and authors began to develop materials useful at the elementary and secondary school levels.

The meaning of computer literacy has never been particularly clear, and it seems to have changed over time. Initially, computer literacy usually was taken to mean a level of understanding which enabled students to talk about computers but which involved little or no experience in working with computers. (This is now called computer awareness.) Students were exposed to movies and talks about computers, allowed to handle a punched card, discussed ways that computers were used in business, government and science, and perhaps toured a computing center. Little or nothing about this was personally relevant to most students, and being aware of computers had little impact upon them.

The growth of computer assisted learning added a new dimension.[3] The computer could teach the student. Certainly this had a direct personal impact upon students. Initial studies suggested that in some academic areas many students learned as well or even better from computers as from conventional modes of instruction. Computer assisted learning required little specific knowledge about computers on the part of either students or

teachers, and computer hardware could be mass produced—a few people predicted that conventional formal education was doomed!

This situation prompted Art Luehrmann and others to raise an important issue in the early 1970s: what are appropriate uses of computers in education?[3] Should the computer teach the student—or vice versa? Or, as Tom Dwyer put it, should the student be the passenger or the pilot?[1]

The basic issues involve what students should learn about computers and the ways they should learn about or use them. When a computer acts upon a student in a computer assisted learning mode, the student need not learn much about computers. But when a student acts upon a computer, developing programs and solving a variety of problems, more knowledge of computers is required—on the part of both student and teacher.

The issues have been sharpened through the work of Seymour Papert. For more than a decade he has been developing the Logo language, turtle geometry, and ideas on using computers with elementary school children. Papert advocates immersing children in a problem-rich environment, and he has shown how computers can help provide this environment.[4] His work suggests that even very young children can become adept at using a computer as an exploratory tool and can learn key ideas such as top down analysis, debugging and subroutine. Papert questions whether our current educational system can cope with the changes he is advocating.

The issues raised by Dwyer, Luehrmann, Papert and others have not been resolved, in part because computer literacy is not accepted as an important goal by the majority of parents, educators or students. Even now the school that can provide one microcomputer or timeshared terminal per 25 students is rare. Rarer still is the school that has even one teacher with a knowledge of computers in education equivalent to a strong bachelor's degree in this field. Contrast this with almost every other academic area taught in secondary schools, where a bachelor's degree or an even higher level of teacher preparation is common.

However, both of these situations are changing—they could change quite rapidly if our society, working through its school system, decided that it was important to have it happen. The increasing personal access to computers may provoke that decision. The remainder of this booklet discusses some aspects of personal computing and how they help to define some specific goals for computer literacy.

PERSONAL COMPUTING: A FORMAT FOR EXPLORATION

Students of all ages can learn to use a computer at a level that is meaningful to them and makes a difference in their lives. Personal computing for students can be divided into several categories. The following uses of computers are neither disjointed nor all-inclusive, but will serve to guide our exploration of the concept of computer literacy. Computers can be personally useful to students as:

I. A General Aid to Learning.
II. An Aid to Problem Solving.
III. An Object of Learning in Itself: The Discipline of Computer and Information Science.
IV. Entertainment.
V. A Part of Their Future.

Each of these will be discussed, along with how each contributes to a definition of computer literacy. The discussion will center around students and their everyday, in-school activities. Thus, the goals for computer literacy that emerge will tend to be student-oriented and relevant to students. Moreover, these goals will be flexible and easily modified as changes occur in computer capability and availability as well as in the curriculum.

I. A GENERAL AID TO LEARNING

Computer Assisted Learning, Tutor Mode

Computer assisted learning (CAL), the use of computers as an aid to learning, can be divided into two major parts. In one part, frequently called computer assisted instruction (CAI), the computer acts upon the student. Whether the mode is drill and practice, tutorial or simulation, the computer has the knowledge and it is the student who is to acquire the knowledge. Following Robert Taylor's ideas,[3] we will call this **tutor mode CAL.**

A second form of CAL puts the student in charge—the student acts on a computer as an aid to learning. Learning environments created using a Logo language-based computer system provide a good example.[14] After a few minutes of instruction, even an elementary school student can learn enough Logo programming to begin encountering interesting and challenging geometry problems. Immediately the emphasis then switches from learning Logo to problem solving in the domain of geometry. We will call this **tutee mode CAL.**[3] It will be discussed later in this section.

In essence, tutor mode CAL is a computer simulation of certain aspects of teaching/learning processes. The field is more than twenty years old now and is slowly maturing. Initially much tutor mode CAL material was

quite poor, and even today this remains a major problem. But, like any computer simulation, tutor mode CAL quality can be improved by continued work on the underlying theory, the software, the hardware and the other supporting materials. There are now some quite good tutor mode CAL materials, with strong evidence that many students learn better and/or faster using these materials. Moreover, tutor mode CAL is an excellent educational research tool, contributing significantly to an understanding of what students learn and what helps them to learn. Good tutor mode CAL embodies what is known about learning theory and makes explicit the model(s) of instruction being used.

The explicit implementation of learning theories in tutor mode CAL is a key idea. All teachers have some insight into a variety of learning theories and realize that not all students learn in the same way. Significant progress in learning theory has occurred during the past twenty years. It is nearly impossible for a classroom teacher to keep up with this progress and to make use of the more relevant ideas in his/her teaching. However, modern theories of learning can be used in the design and implementation of tutor mode CAL materials. An individual or team of tutor mode CAL developers can spend the necessary time to study current learning theory research and to implement ideas that will help students learn more, better and faster. Tutor mode CAL can provide an individualization of instruction that cannot be matched by a teacher who must deal with large numbers of students.

Another important idea that can be made explicit in education is learning about learning. A student needs information on how, and under what conditions, s/he can learn best. That is, a student needs to learn about learning. The computer provides a good motivation and vehicle for specific instruction on learning and on learning to learn. What does it mean to "know" a particular topic? Are some methods of studying more productive than others? Is there one best method for studying all subjects? Since computers can help most students to learn faster, most students can benefit from learning the capabilities of tutor mode CAL and from having access to tutor mode CAL. Any student can learn to use tutor mode CAL and all can learn how (for them personally) CAL compares with other aids to learning.

Ideally, a computer literate student has experienced tutor mode CAL in a variety of disciplines and has developed insight into its value relative to other modes of instruction/learning. The student has used drill and practice, tutorials and simulations in art, music, math, science, language arts, social studies and so on. This has occurred at each grade level. The student has studied and thought about what it means to learn and has specifically studied various modes of instruction/learning. The student understands what best fits his/her needs in a wide variety of situations.

Notice that this aspect of computer literacy is sensitive to changes in computer technology and to changes in tutor mode CAL quality and avail-

ability. We need to acquaint students with the best that is currently available and help them to understand that this "best" is rapidly changing. We should also stress that tutor mode CAL can occur in many settings outside the classroom and can therefore play a useful role in lifelong education.

This approach to computer literacy can begin at the elementary school level and can continue throughout a student's education. It has the potential to help revolutionize education. The responsibility for learning can be placed more explicitly upon the student, rather than upon the teacher or school system as it is now. Many topics of instruction and learning do not have to be directed by the teacher nor do they require that a teacher be present. It is likely that eventually tutor mode CAL will be a standard, or even dominant, mode of instruction/learning. Because of this and other benefits of tutor mode CAL discussed in this section, we should continue to expand usage of tutor mode CAL, even in situations where it is not yet 100% cost effective relative to conventional modes of instruction. By doing so we are investing in the future value of our students' education.

Some teachers fear that tutor mode computer assisted instruction will disrupt the school system and replace teachers. This will certainly not be true in the near future. The number of microcomputers currently being used in the United States precollege education system is enough to give each student one minute of computer use per day. A ten-fold or twenty-fold increase in computer assisted learning would still have only modest impact.

But by the year 2000, we may well have one microcomputer for every two students. A typical student may use computer assisted instruction materials for an hour or two per day. The computer, rather than textbooks and other print materials, may be the dominant mode of instruction. The potential impact upon teachers is not clear.

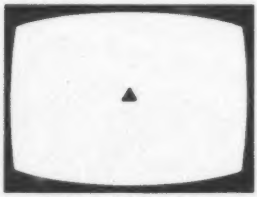
Computer Assisted Learning, Tutee Mode

In tutee mode CAL, a student acts upon a computer; the student is in charge, directing the interaction and learning by doing. The computer helps to provide a rich learning environment, but the computer is not preprogrammed with information to be taught to a student. Tutee mode CAL generally requires that a student learn quite a bit about a computer system and its language.

Reading provides a good analogy. A young student must expend considerable effort to master the rudiments of reading. Initially a student's aural and visual skills far exceed his/her reading skills in acquiring new information. But eventually reading skills increase and a new world opens—the printed record of the accumulated knowledge of the human race. Third graders may learn more about dinosaurs than their teachers know. A seventh grader may read about electricity, attaining a level of knowledge far beyond that of leading scientists two hundred years ago.

Similarly, students first encountering computers and a programming language in tutee mode CAL must focus upon learning the rudiments of a programming language. But eventually enough of the language is learned to open up new worlds for exploration and learning. If the computer and language system are appropriately designed, most students can move rapidly from an emphasis on the study of the computer system into an emphasis on learning other material.

The Logo language illustrates this quite well. Logo was specifically designed to be used in tutee mode CAL by elementary school students. Initial instruction may consist of learning to turn on the computer system and being shown a few simple examples. When the system is turned on, a pointed arrow called a "turtle" is displayed. This turtle draws lines as it moves about the screen following directions specified by the computer user.



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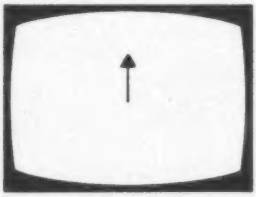

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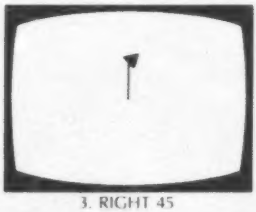

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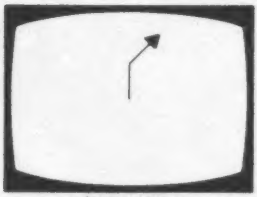

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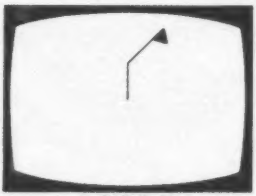

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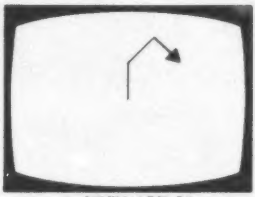

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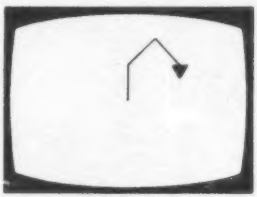

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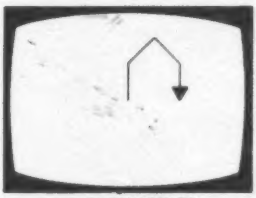

8. FORWARD 70

Even very young children can quickly learn commands such as FORWARD, BACK, RIGHT and LEFT. FORWARD and BACK are accompanied by a distance while RIGHT and LEFT are accompanied by an angle measured in degrees. The commands have abbreviations FD, BK, RT and LT respectively.

Already the child is dealing with distances and angles—that is, with geometry. How can the turtle draw a house, a clown or a flower? After just a few minutes of instruction, the focus changes from learning Logo to the solving of some problem.

As students progress, they will find a need for additional Logo language tools. Thus, students will repeatedly switch from working on a problem to learning more about the language and then back again to the problem.

In the above example the Logo system is used to create a geometry environment. This is a rich, deep environment; an entire secondary school geometry course has been embedded in this environment.[5]

A modern word processing system provides another example of tutee mode CAL. Such a system allows material to be typed, edited, stored and output. It also contains a spelling checker, which can help to identify misspelled words.

It requires some initial effort for a student to learn to use a word processing system. But the rewards are well worth the effort. Writing becomes more fun and correcting errors is no longer a major problem. A student can go through a number of drafts of a report or essay, trying out various ideas and continually improving the quality. The nice looking computer printout is a potent reward.

In the past, word processing has been quite expensive, so it has been used primarily in large business offices. Now, however, microcomputers have brought the cost of word processing within the reach of many millions of potential users. It is evident that most offices will eventually make use of this technology. As word processing comes into our educational system at all levels, the impact will likely prove to be dramatic. Debugging, the systematic detection and correction of errors, will become a standard part of writing. Because the final product is nice to look at, more students will collect and display their writing. Perhaps we will spawn a new generation of writers!

The key idea of tutee mode CAL is using a computer system to create a new, rich, interesting learning environment. Tutee mode CAL can provide environments such as art, music, the physical sciences, and so on. In music, for example, we know that quite young children can develop a good ear for music and can learn to play musical instruments. With an appropriate computer-based environment, the same children can also compose music. The computer interacts with the composer, stores the composition and plays it when requested. The composer (the child) creates the musical composition, edits it and experiences the pleasure of being creative.

Art education provides another good example. There now exist excellent computer assisted "painting" programs. A student can paint a picture on a color television screen. Working with the computer system, the

student can animate a picture, change the shape, size and color of its objects and experiment with perspective. Such experimentation is a powerful aid to learning art. Moreover, it provides a solid foundation for learning about computer graphics and for understanding how computers are used in the production of television and movies.

Tutee mode CAL can be done on any computer system. But obviously it will be more successful if the hardware and software are specifically designed to facilitate learning. An interactive Logo system is far superior to a batch processed COBOL system for young children. Eventually we will have a wide variety of computer hardware/software systems specifically designed to facilitate tutee mode CAL. In some disciplines it is likely that tutee mode CAL will prove to be a more superior aid to learning than conventional modes of instruction or tutor mode CAL. In the years to come, tutee mode CAL will certainly play an important role in education.

Tutee mode CAL is in its infancy. Since the research and experience bases are still quite modest in size, it is difficult to formulate precise student-oriented computer literacy goals in this area. Certainly all students should have an opportunity to explore a variety of learning environments based upon tutee mode CAL. Word processing, geometry, art and music learning environments are available through several different computer systems. These provide a good starting point for introducing students to the power and pleasure of using tutee mode CAL. As with tutor mode CAL, part of the goal is to help students learn about learning. Some students will find that tutee mode CAL is especially suited to their learning styles and academic interests.

The foundation of tutee mode CAL is discovery-based learning. A computer system is used to help create a rich educational environment and the student is encouraged to work in this environment. For many students, discovery-based learning is very effective—rapid and deep learning does occur.

But there are many other students who seem to flounder in a discovery-based learning environment. They need a more structured environment and more guidance from teachers.

The same two points can be made for teachers. Some teachers function well in a discovery-based learning/teaching environment. But many others have had little or no experience and instruction in discovery-based learning/teaching. For them, tutee mode CAL may be quite threatening.

II. AN AID TO PROBLEM SOLVING

Problem solving is a central and unifying theme in education. Any discipline can be framed as a hierarchic set of problems to be solved. Instruction in a discipline leads to understanding the nature of its problems: what problems have been solved and ways to solve some of these problems;

what problems have not been solved and ways to formulate and attack new problems.

A key aspect of problem solving is building upon the work of others. This work is stored in a variety of ways. Each discipline has developed vocabulary, notation and tools specifically designed to aid in representing and solving its problems. The vocabulary of mathematics, music and psychotherapy are each highly specialized, and a given word may have different meanings in these three disciplines. For example, a group in mathematics is not the same as a group in psychotherapy. The vocabulary in each discipline has been carefully developed to allow precise communication of important concepts in the field. Books, journals and other writings are "coded" in these vocabularies, and they constitute a standard way of storing the accumulated knowledge of a field. Still and motion pictures, video recordings and audio recordings are other modes of storage.

Much knowledge is stored in the form of machines that people learn to use: the telescope, microscope, telephone, television, clock, radio, automobile, and so on. A person can learn to use these machines to solve various problems without mastering all the details of constructing the machines or understanding how/why they work in the manner they do. Very young children can learn to use a telephone, television or record player.

The embodiment of information in a machine is a key idea. A young child can learn to read music and to play a musical instrument without learning the details of music theory or the design and construction of musical instruments. A child can learn to use a telephone system; a young adult can learn to drive a car. All of these activities involve building upon and using the work accomplished by others.

Computers, although they are also "merely" machines, provide a unique, new way to store knowledge. We can (roughly) divide the computer storage of knowledge into two categories—passive and active. Passive storage in a computer is analogous to storage in the form of books, films, etc. Computer storage may be more efficient perhaps, but not qualitatively different. Written materials can be stored on a magnetic disk or tape, and the material can be retrieved with the aid of a computerized information retrieval system. Similarly, pictures or sound can be digitized for computer storage and later reassembled for playback. This may be faster and more convenient than non-computerized methods, but in itself does not represent a profound change.

Active storage of information is illustrated by even the simplest four function calculator. The calculator "knows" how to add, subtract, multiply and divide. It stores this knowledge in an easily usable form. This sort of active storage of knowledge is akin to the storage of knowledge in other machines such as the telephone, microscope, alarm clock or stereo system.

Computers epitomize active storage; they are specifically designed for both the storage and retrieval of information, and for the manipulation of the stored information. A computer program can contain information on how to do something in a form that the computer can use to carry out the actual process. The computer can act upon the world, controlling industrial processes, routing telecommunications and helping to solve a wide variety of other problems. A computer can be a relatively smart machine, storing and using knowledge and skills beyond those of many of its users.

The active storage of information normally shortens the time it takes to manipulate or retrieve the information, as well as changing the knowledge and skills needed. Even the four-function calculator illustrates this. Grayson Wheatley estimates that a typical student spends two years of mathematics education instruction time in grades 1-9 mastering paper and pencil long division.[6] How radical is it to suggest that the time spent on this topic be halved and that students be given calculators?

The calculator example is particularly interesting because of its potential to greatly change arithmetic education. With some assistance from teachers, almost all first grade students can develop an intuitive understanding of addition, subtraction, multiplication and division. They can develop the ability to mentally solve simple examples of all four of these types of problems.

But progress in developing paper and pencil computational skills is slow. A typical student learns paper and pencil addition and subtraction by the end of the third grade and then moves on to multiplication and division. Consider the impact of giving all third graders calculators and allowing their unlimited use. The emphasis would be changed from computation to problem solving—from rote memory to higher level cognitive processes. Little research has been done upon this type of possible change to the curriculum.

And if calculators have the potential to make such a large change in the curriculum, what about computers? Eventually, computers will be nearly as common as calculators are today. What *should* students be able to do mentally? with pencil and paper? assisted by a calculator or computer? These are very difficult questions and will certainly challenge educators for decades to come.

Progress in hardware, software, artificial intelligence and computer assisted problem solving in all disciplines is continuously expanding the totality of problems that computers can solve or help to solve. The idea of a knowledge-based computer system is now well entrenched and growing in importance. What does a chemist, geologist, mathematician or physician know that a computer might be programmed to know? In these and many other disciplines, intense research efforts are producing computer systems that perform at an expert level. That is, computer systems can solve or help solve a variety of nonroutine problems complex enough to challenge a

human expert. The number of these expert-level knowledge-based computer systems will grow rapidly over the next ten to twenty years. Thus, for any particular problem area that a student might study, it is likely that computers are already a very important aid in problem solving and that the importance of computers in that area is growing.

The computer literate student understands and uses computers as an aid to problem solving. This means that the student has studied problem solving and a variety of aids to problem solving. The student has used computers as an aid to problem solving over a period of many years in a wide variety of disciplines and understands their capabilities and limitations. Given a problem, the truly competent student can decide if a computer is a useful aid compared to other aids/approaches to solving the problem.

If a computer is to be used to help solve a problem, appropriate software is necessary. Previously written programs (often called canned programs, library programs or packaged programs) are readily available for many general types of problems. Some of these library programs are easy to use and easy to learn how to use. Others require substantial instruction and practice. Indeed, learning to use certain packaged programs is roughly equivalent in difficulty to learning a general purpose programming language. There is no clear dividing line between programming and using problem-oriented packages of library programs.

In many situations an appropriate library program is not available. An existing program may need to be modified, several pieces of existing programs may need to be combined or a new program may need to be written. Thus, instruction in computer programming surfaces once again as an important part of computer literacy. We will discuss this in more detail later.

If the use of computers as an aid to problem solving is taught and integrated into the curriculum, some parts of the curriculum will substantially change. The greatest changes will be in areas where we know a lot about problem solving such as in mathematics and the sciences. But our curriculum contains a number of other areas in which a computer can solve problems or can be of substantial assistance in solving them. We will need to decide what we want students to learn to do by "conventional" methods and to what extent "knowing" an area includes knowing how to make use of a computer to solve problems in this area. Students need to know which aspects of the problems they are studying can be handled by a computer.

The ideas of computer literacy raised in this section are dependent upon the capabilities of computer hardware and software and so will change over time. As with CAL, students should become familiar with the best of modern hardware and software, since continued rapid progress is to be expected in both. This type of computer literacy is multidisciplinary. Its proper achievement requires that teachers be computer literate with respect

to their own disciplines. The Association for Computing Machinery has made recommendations on teacher education.[7]

Most teachers today are not computer literate within their own teaching areas. They do not know how computers can help solve the problems of their disciplines. Moreover, most schools of education are not yet producing computer literate graduates. For the next decade or two our educational system faces a serious problem. Computer systems will become increasingly capable aids to problem solving, while the computer knowledge of most educators will continue to lag far behind. It will take a distinct effort on the part of our educational system to significantly improve this situation.

The teacher education problem is being attacked from two directions. First, many school districts now have computers-in-education committees that work to set student-oriented goals and to develop the needed teacher inservice courses. Second, colleges of education are beginning to put significant effort into both preservice and inservice computer education. A recent collection of eighteen papers discusses what various colleges of education are doing and gives recommendations for this phase of teacher education.[15]

III. AN OBJECT OF LEARNING IN ITSELF: THE DISCIPLINE OF COMPUTER AND INFORMATION SCIENCE

Computer and information science is a new and important discipline. It is now well established in most major colleges and universities and is rapidly growing in stature. In the United States alone there are nearly 400 bachelor's degree programs and nearly 100 doctoral programs in this field. Hundreds of journals devote all or part of their content to computer and information science topics, and the research journals of almost every other discipline occasionally carry computer-related articles.

Computer programming is one part of computer and information science, and learning some programming is an essential step in understanding computer and information science. We are talking about a student-oriented, non-professional level of computer programming knowledge and skills. A student should be able to program well enough to be able to attack the types of problems being studied in the school curriculum and to make effective use of the tools being taught. When the topic being studied is part of computer and information science, it is even more important that students write programs.

Computer programming involves learning a language. More importantly, it involves developing and practicing problem-solving skills. Top down analysis, segmentation, testing and debugging are fundamental ideas best learned through hands-on experience. These programming-related ideas carry over to problem solving in many other academic areas.

Thus, we are led to include computer programming as part of computer literacy via our analysis of tutee mode CAL, through our analysis of problem solving, and also through the importance of computer and information science. But none of these gives a precise statement of the level or nature of programming skill appropriate to computer literacy.

To specify goals for computer programming instruction more precisely, we need to define what it means to program. Many interactive computer systems function in both an immediate execution and a delayed execution mode. In the immediate execution mode, statements such as FORWARD 50 from Logo or PRINT 72/389 from BASIC are immediately carried out by the computer. These statements can be thought of as one-line programs. A student who writes such statements is programming. Even this level of programming skill is useful in learning geometry, arithmetic or more about programming. In the delayed execution mode, a student prepares a sequence of one or more statements and enters it into a computer system. After entering the sequence of statements, the student can direct the computer to execute the program.

Word processing and information retrieval also provide examples of computer systems that have both immediate execution commands and delayed execution capabilities. Learning to use a word processing system or an information retrieval system is learning to program. It is true that one is learning a special-purpose language, rather than a general-purpose language such as BASIC, Logo or Pascal. However, the same general principles apply, and it is clear that the computer user is directing the system.

In both the immediate execution and the delayed execution modes, a student is making use of very sophisticated software. In the early years of computers, most available software was written in a general-purpose language. However, there has been a strong historical trend towards special-purpose software systems. This became evident quite early in statistics. For more than 20 years now, there have been quite sophisticated statistical program packages. Learning to use such a system is comparable in difficulty to learning a general-purpose programming language.

One of the most successful and widely used applications systems for microcomputers is known as an electronic spread sheet. In essence, the computer display becomes a large two-dimensional table. Columns in the table may be related to each other by simple formulas. Then, changes to the figures in one column cause automatic updates to figures in other columns. The electronic spread sheet is such a useful tool to many business people that they purchase a computer system just for this particular application. It is quite appropriate that business-oriented secondary school students learn to use such systems.

Including the use of information retrieval, word processing, statistics and other applications systems in our definition of programming greatly broadens the scope of what it means to learn to program. Learning to use appli-

cations systems is a rapidly growing part of computer programming; it will eventually be the dominant part. All students can learn to use applications systems, and this is an essential part of becoming computer literate.

In having students learn to program, the goal is to attain a functional level of knowledge and skill—a level useful in studying and attacking problems in every academic area. The analogy with reading and writing is again useful. For a first grade student, reading and writing are specific academic disciplines; it takes considerable effort to learn to read and write. But a high school student uses reading and writing as tools to study other disciplines.

Our educational system has had many hundreds of years of experience in helping students learn to read and write. We know that most students can develop a functional level of reading and writing literacy. We know that instruction can begin in the first grade or earlier and that the rate of progress toward functional literacy varies considerably among students. Moreover, we recognize there is a significant difference between a functional literacy level and a professional level. Some students study journalism, writing and literature in college or graduate school. They develop much higher levels of skill and knowledge in reading and writing than the general populace.

Our educational system has only limited experience in helping children learn to program a computer. But we know that if appropriate computer facilities and teacher knowledge are available, then elementary school students can learn to program. A child's initial exploration of Logo can be a valuable learning experience. The experience rapidly gets into problem areas such as geometry where the computer system and the student's programming skills become useful aids in learning new non-computer material.

The use of word processing at the elementary school level is in its infancy. Seymour Papert's work has shown that even learning disabled children can learn to use a word processing system. There is some evidence that success in using word processing carries over to other academic areas, leading to an overall improvement in academic performance.

Given adequate time, computer access and instruction, most middle school and junior high school students can learn to program in a language such as BASIC, Logo or Pascal. Such students can learn to use an information retrieval system, a word processing system and other applications systems. Currently, the great majority of computer programming instruction at the precollege level focuses upon general-purpose language systems, especially BASIC. This emphasis will gradually shift as students and educators come to appreciate the value and power of the applications systems.

The key to functional computer literacy is having a supportive environment in which students can continue to use the computer knowledge and

skills they are acquiring. A seventh grade student can learn to use a word processing system and an information retrieval system. These are general-purpose tools—the student can use them in almost all academic areas. Skill in using these systems will grow as the student grows in overall academic accomplishment, provided adequate computer access and encouragement are available.

Another example is provided by computer graphics systems. A graphics system makes it possible for a person to easily draw a bar graph, pie chart, scatter plot or function graph. Drawing graphs is useful in social sciences, physical sciences and mathematics. Initial exposure to a comprehensive graphics system might occur in the ninth grade. Subsequently, students could use this system in a variety of courses for the remainder of their educational careers.

To be more specific, consider a student progressing through the typical algebra, geometry and second year algebra sequence of courses. Computer graphics is a useful tool in all of these courses, both as an aid to problem solving and as an aid to understanding the topics being studied. Graphical representations of functions, for example, can help to improve one's intuitive insights into functions and their uses. A computer literate student taking these math courses would understand uses of computer graphics in the courses and would make frequent use of this important tool.

Along with instruction in special-purpose and general-purpose computer programming systems should come instruction in computer science. Introductory ideas can be woven into the curriculum at all academic levels. A formal computer science course might be given at the high school level.

The Association for Computing Machinery (ACM), working through its Elementary and Secondary Schools Subcommittee, has developed a year-long computer science course for high school students.[8] The course is intended to be roughly comparable to high school biology in its difficulty, and the hope is that eventually it will have a similarly wide audience. The course has a relatively low mathematics prerequisite. Its content is balanced between computer programming, problem solving and a variety of topics from computer and information science. A detailed, week by week outline for such a high school computer science course is given in Jean Rogers' booklet, *An Introduction to Computing: Content for a High School Course*, published by ICCE.[9]

Computer science includes topics such as artificial intelligence, business data processing, computers and society, computer graphics, information retrieval, and modeling and simulation. It also covers the design, representation, testing and debugging of procedures to solve problems. These latter ideas carry over to other (non-computer) academic areas, providing students with some general-purpose problem-solving skills.

These skills and their underlying ideas are quite useful and powerful. Consider debugging. Currently, most students are taught that the math work they do is either "right" or "wrong." They do not explicitly learn that their "wrong" work may be mostly correct and merely need some debugging. Contrast this with learning to write. The idea is well accepted there that a student's work may need debugging. Teaching the idea of bugs and debugging could profoundly change mathematics education at the precollege level.

It is perhaps too early to say that a high school level computer and information science course is an essential part of computer literacy. But already we can see movement in that direction on the part of some colleges and universities. That is, it seems likely that ten years from now many colleges and universities will place entering freshmen into a remedial computer literacy course if they have not acquired such knowledge previously.

It is also difficult to know what employers will expect of students entering the job market ten years from now. The rapid proliferation of computers suggests that quite a high level of computer literacy will be expected. The ACM course might become part of a definition of the expected level of computer literacy.

The standards for computer literacy discussed in this section tend to come from higher-level authority (for example, the ACM or ICCE), rather than being apparent to the student. Not all students will easily accept that an ACM or ICCE-recommended body of knowledge and specific skills will be useful on the job or in college. Moreover, we cannot say with certainty that such a course is indeed appropriate. For many years to come, people will be able to acquire needed levels of computer-oriented skills on the job or in their higher education programs. But precollege students who have acquired this level of computer literacy will have a distinct advantage in seeking jobs and/or in continuing their formal education.

Although this booklet focuses mainly on precollege computer literacy, the emerging pattern of college level computer literacy provides useful information. In the past few years enrollment in college computer science and computer literacy courses has doubled and then doubled again. College students are aware of the value of having a solid functional level of computer science knowledge. It is likely that this awareness will spread to high school students, leading to a rapid growth in demand for computer-related courses. Most colleges are hard pressed to meet the demand, and the same problem is likely to occur in many high schools.

IV. ENTERTAINMENT

Computers are a rapidly growing form of entertainment. They compete successfully with television, stereos, books and movies. They are quite important in the lives of many students and can have either a negative or a positive effect. We should remember that the typical eighteen-year-old in

the United States has watched more hours of TV than s/he has attended school! Twenty years from now we may be making similar statements about student use of computerized entertainment systems.

As with CAL, use of computers as a form of entertainment can be divided into two main categories. The designing and implementing of programs is fun for some students. If the program plays a game or simulates an alien environment, it is especially fun. Some people spend a significant percentage of their leisure time writing, testing and improving such programs. They often develop a very high level of programming skill, a level which generally exceeds the skill most students develop through programming courses offered in schools.

But the great majority of computer use for entertainment is game playing. Some computerized games can be learned and perhaps even mastered in a matter of minutes; however, there is a growing collection of computerized games requiring dozens or even hundreds of hours of effort to master. Extensive learning or the development of a high level of hand/eye coordination is needed.

Typical of the sophisticated computer games are the computerized variations of Dungeons and Dragons. These are fantasy games in which one explores multi-leveled dungeons, searching for treasures and fighting dragons and other creatures. The games are quite complex and playing them well requires a good memory, good attention to detail and concentration. While careful studies of their educational value have not been done, it seems evident that such games are intellectual in nature, and thus have educational value. Who is to say that learning to play chess is a better use of one's time than learning to play a computerized fantasy game?

Quite good computer programs now exist to aid musical composition or ear training, and computerized aids for artistic creation are also available. It is not difficult to include these in the realm of entertainment, but they also have clear educational value.

A computer program to play chess, checkers, backgammon or Othello can be a challenging opponent and an excellent aid to learning one of these games. Many other problem-solving situations can be formulated as interesting games, involving both entertainment and learning.

There is no clear dividing line between entertainment and education. Indeed, if learning is fun, more and better learning tends to occur. Thus, students should be given the opportunity to make use of CAL materials that are both educational and fun. They should learn to be critical of learning aids that are unnecessarily dull.

There appears to be little need to give students instruction in how to use a computer as a form of entertainment. Students quickly learn this on their own or from their peers. But the study of entertainment, or more appropriately the study of leisure time, is now considered to be important in modern education.

A computer literate student has experienced the use of computers as a form of entertainment in a variety of situations. The student has studied various forms of leisure time activity and how computers fit into this field. The student has made a conscious and reasoned decision as to the role computerized entertainment will play in his/her life at the current time.

V. A PART OF THEIR FUTURE

Students in junior high and high school often are actively interested in the social problems of our society. They study these problems, and they begin to work toward helping solve the problems. While computers are useful aids to problem solving, they are also a new source of problems. For example, computers make possible very large, easily accessible data banks. Such data banks may contain detailed records on a person's schooling, criminal history, federal and state taxes, medical history and employment. The 1984 "big brother is watching" era is nearly upon us.

A computer literate student has studied the role of computers and privacy. The student is knowledgeable about the capabilities and limitations of computerized systems that store data about people and their activities. The student is able to function as a well-informed citizen in helping to preserve individual freedoms and those aspects of individual privacy that are so important in our society.

Computers represent change, and computers are a change agent. It is generally agreed that one major goal of education is to help students prepare to cope with situations they will encounter later in life. Every student will encounter new and different situations; every student will encounter change.

Many of these changes will be based upon developments in science and technology. We can expect continued rapid progress in such diverse fields as medicine, genetic engineering, telecommunications and automation.

At the heart of scientific and technological progress is the accumulation and application of knowledge. And it is here that computers are making a substantial contribution. Computers, supported by the general knowledge being developed through the field of computer and information science, have become an indispensable part of our science and technology.

Moreover, computers are one of the most rapidly changing parts of science and technology. The rapid progress in computer hardware, software and applications that we have seen in the past thirty years seems destined to continue for the next thirty. These past thirty years have taken us from the UNIVAC I, costing well over a million 1951 dollars, to the portable and/or handheld microcomputers of today. Many of these microcomputers exceed the UNIVAC I in capability, while costing less than one-thousandth as much!

It is fun to make a conjecture about what the next thirty years will bring. The Dynabook project and Smalltalk-80 language based on Alan Kay's ideas are especially exciting.[10] Work began at Xerox Corporation in the early 1970s on a handheld computer that would have a high resolution graphics display screen and a very powerful, modern language. Preliminary versions of the Smalltalk language were extensively tested with children, although the overall development project is now aimed mainly at other markets.

Thirty years from now we can expect to have inexpensive handheld computers that exceed today's million-dollar machines in capability and ease of use. Computers will be more common than television sets are today. There will be large libraries of programs that can be used to help solve a continually expanding range of problems. All educated people will make everyday use of these computer libraries.

It is important that students understand the rapid changes that are occurring in the computer field and what the future is apt to bring. In particular, how will computers affect the job market and the types of jobs that are available? Current estimates are that computer-based automation of manufacturing in the United States will eliminate ten million jobs over the next twenty years. The office of the future will utilize word processing, computerized information retrieval and electronic mail. Knowledge and skills needed to function in this office environment of the future are different from the knowledge and skills that most students are acquiring in today's schools. The publishing and advertising industries will be drastically changed by computerized video disks and computerized information retrieval systems in people's homes. The postal system will be substantially changed by electronic mail.

A student who understands these potential changes can plan accordingly. Decisions on education and career goals should take into consideration how computers are changing our world. This is an important part of computer literacy.

FINAL REMARKS

One common way to talk about computer literacy is to discuss knowledge, attitudes and skills. Various instruments have been developed to test these aspects of computer literacy, and test scores serve to define levels of competency. Another approach is to specify course goals and objectives and to develop specific course content to implement these goals, such as Neill and Ricketts have done.[11,12]

In late 1982 the U.S. Federal government made a grant to the Educational Testing Service, Princeton, New Jersey to work on developing a definition of computer literacy and an instrument to measure literacy. Part of the work on the project has been subcontracted to the Human Resources Research Organization of Alexandria, Virginia. The idea is to do a national

study of school superintendents, principals, teachers and students to measure their levels of computer literacy.

The approach being taken is based upon the work of Neill and Ricketts.[11,12] It will include a multiple item test plus the gathering of some information on how these groups of people actually use computers. Likely the computer literacy measurement instruments will be ready for initial testing in the fall of 1983.

We have not attempted to use these approaches here, nor have we discussed their merits. Rather, we have used a different approach, based on the idea that a computer can have a personal impact upon the student, and that the student will be self-motivated to acquire a certain level of computer literacy because of the personal value of computers. This assumes, of course, that appropriate learning opportunities are made available to students. Students need easy, everyday access to computers if the personal computing ideas of this paper are to be implemented successfully. Moreover, students need computer literate teachers.

The conclusion reached in this booklet is that computer literacy is a functional knowledge of computers and their effects on students and on the rest of our society. This knowledge should be at a level compatible with other knowledge and skills a student is acquiring in school. It is a knowledge based on understanding how computers can help us learn, how computers can help us solve problems, what computer knowledge is essential to a modern understanding of other academic areas, what is included in the field of computer and information science, computers as entertainment and what role computers will play in our changing world. This approach to computer literacy changes easily as computers become more readily available and easier to use, as we learn more about computers and integrate the knowledge into the curriculum, and as the use of computers becomes commonplace in homes, businesses, government and schools.

If students are to acquire a functional knowledge of computers, our school system will need to provide substantial computer equipment and instruction. New courses will need to be developed and many current courses will need to be revised. Support materials such as lesson plans, student workbooks, textbooks, films and other computer-oriented materials will need to be developed. Teachers will need to develop their own computer literacy.

The problem is large, but the goal is clear. Functional computer literacy is important for all students.

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GLOSSARY

Algorithm

A finite, step-by-step set of directions guaranteed to solve a specified type of problem. Students learn algorithms for addition, subtraction, multiplication and division of multidigit positive whole numbers. They also learn algorithms for looking up a word in a dictionary and for alphabetizing a list of words. A computer can carry out the steps in many different types of algorithms. Thus, the study of computers and the study of algorithms are closely related subjects.

Artificial Intelligence (AI)

How smart can a machine be? Artificial Intelligence is the branch of computer science that studies this question. Computers can play games such as checkers and chess. They can carry on a conversation in English via computer terminal, aid in foreign language translation and carry out some of the tasks that a teacher currently performs to help students learn. Education is faced with the problem of deciding what students should learn to do mentally, what they should learn to do using pencil and paper and what they should learn to do using other aids such as a computer or a calculator. Progress in AI continually extends the capabilities of computers and thus complicates the problem.

BASIC (Beginners All-purpose Symbolic Instruction Code)

The most widely used computer programming language, originally designed for use by college students. BASIC is available on most inexpensive computers and is widely taught and used in secondary schools. Although BASIC is sometimes taught to grade school students, there are other languages that are more suitable for use by children of this age level. (See *Logo*.)

Binary digit (Bit)

One of the symbols 0 or 1. The binary number system uses just these two digits to represent numbers. Since numbers and other quantities inside a computer are coded using a binary code, it is often felt that it is necessary to understand binary arithmetic in order to understand computers. This is not correct, and the existence of computers is not a good justification for trying to teach binary arithmetic to grade school students. Most adults who make use of computers on their jobs do not understand binary arithmetic.

Bug

An error. In the computer field, bugs are often classified as software bugs (errors in a program) or hardware bugs (flaws in the physical machinery).

Central Processing Unit (CPU)

This is the part of the computer hardware that takes instructions from computer memory, figures out what operations the instructions specify and then carries out the instructions. The CPU of a middle-priced modern computer system is able to process several million instructions per second.

Chip

The transistor was invented in 1947 and proved to be an excellent replacement for vacuum tubes in many applications. During the 1960s people learned to manufacture a circuit containing a number of transistors and other electronic components all in one integrated unit. This was called an integrated circuit. Since a small "chip" of silicon was used in the process, it was also called a chip. Continual rapid progress in developing smaller and smaller circuitry has led to the current situation where a single chip may contain the equivalent of tens of thousands of transistors and other electronic components. Such chips can be mass produced, often at a price of well under $10 each. A single chip may form the heart of a calculator or be the central processing unit of a microcomputer.

Computer
An electronic digital machine designed for the input, storage, manipulation and output of alphabetic and numeric symbols. It can automatically and very rapidly follow a detailed step-by-step set of directions that has been stored in its memory. (See *Hardware* and *Software.)*

Computer Assisted Learning (CAL)
Any use of computers to help students learn. In tutor mode CAL, the student is acted upon by the computer—the computer teaches the student. In tutee mode CAL the student is in charge, directing the computer. Both forms of CAL are important in a modern education.

Debug
To remove the bugs (errors) from a computer program or other set of directions, or to correct flaws in computer hardware.

Disk
A storage device consisting of a flat circular plate coated with magnetizable material such as iron oxide, the same type of material used to coat magnetic tape. If the disk is made of flexible plastic, it is called a floppy disk. If it is made of rigid metal, it is called a hard disk. A floppy disk may store 100,000 to 150,000 characters and costs $3 to $6, while a hard disk pack may store 300 million characters or more and is more expensive.

Graphics
Computers can be used to input, store, manipulate and output architectural and engineering drawings, maps, pictures and so on. This aspect of computer science is called computer graphics.

Hardware
A computer system consists of both physical machinery, called hardware, and computer programs, called software. The five main hardware components of a computer are input units, primary storage, central processing unit, secondary storage and output units. For an inexpensive microcomputer system, the input and output units are combined in a typewriter-style keyboard terminal, and secondary storage may be via an inexpensive cassette tape recorder.

Information Retrieval (IR)
The branch of computer science that deals with the storage and retrieval of large amounts of information. The collection of information that can be accessed is often called a data bank. A large data bank may contain as much information as a large library of books.

Logo
A computer programming language developed specifically for children by Seymour Papert at Massachusetts Institute of Technology. It is an excellent language to use to introduce computers into the elementary and secondary school classroom.

Microcomputer
A computer whose central processing unit consists of one or a few large scale integrated circuits (see *Chip*). Microcomputer systems range in price from about $100 to $8,000 or more, and millions of these machines have been sold in the past few years. They are becoming a common item in both homes and schools.

Microsecond
A millionth of a second. A modern, medium-priced computer can carry out an operation such as multiplying two numbers in less than a microsecond.

Modeling and simulation

A model is a representation of certain key features of an object or system to be studied. Scientific models often make use of complex formulas and involve substantial use of mathematics. If a computer is used to solve the equations and carry out the necessary calculations, the process is called a computer simulation. Modeling and simulation are essential tools in every area of science, as well as in economics, business and a number of other fields.

Nanosecond

A billionth of a second. The most expensive computers now being manufactured can carry out an instruction in less than two nanoseconds. Such a machine will execute more than 500 million instructions in one second!

Programming language

Each computer is constructed to be able to follow (execute) a program written in its "machine language." The machine language for a particular machine consists of perhaps 60 to 300 different instructions, and different makes or models of computers tend to have different machine languages. A number of more universal, high-level computer languages have been developed such as BASIC, COBOL, Logo, FORTRAN and Pascal. Each language is designed to be particularly useful to a specified group of people. For example, COBOL is designed for use in business and BASIC is a student-oriented language. A particular computer can use one of these languages only if a translating program has been written to translate statements from the language into the computer's machine language.

Software

A computer system consists of both physical machinery, called hardware, and computer programs, called software. Both are necessary if the system is to perform a useful function. Language translators are one type of software that allow programmers to use languages such as BASIC, COBOL, Logo and Pascal. These programs translate from the aforenamed languages into the machine languages of specific machines. A computing center often maintains a large library of programs designed to solve a wide variety of problems. Such a software library is an essential tool for most people who use computers on their jobs.

Timeshared computing

A form of interactive computing in which a number of terminals are connected to a single computer system and share its resources. The system can be designed to allow easy communication among the users. Typical applications are airline and motel reservation systems, stock market quotation systems and multi-user interactive instructional computing systems.

Word processing

Use of a computer as an automated typewriter. Paragraphs of standard materials, as well as rough drafts and complete documents, are stored in computer memory. These may be edited or modified using a typewriter-like keyboard terminal. Error-free final copy can be rapidly printed out by the computer on a terminal.

The Computing Teacher, **published nine times per year, contains many articles related to computer literacy and to other aspects of computers in precollege education. The 1982-83 price for a nine-issue subscription is $16.50 for U.S. subscribers and $20 outside the U.S. The order address is the same as for this booklet.**

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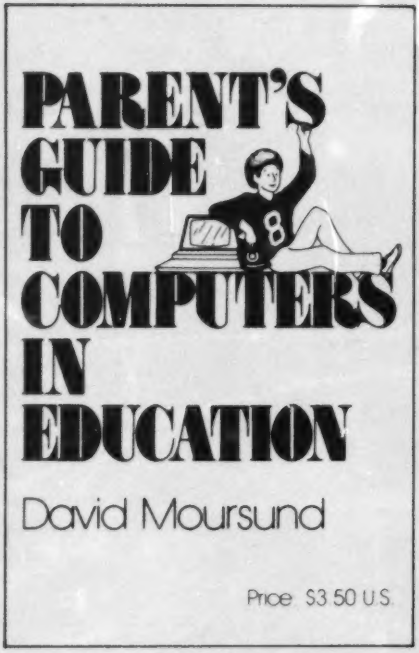

PARENT'S GUIDE TO COMPUTERS IN EDUCATION

David Moursund

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Comes the Dawn
(If Only I Can Find the Switch)
by Merle Marsh
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ABSTRACT

Parents already feel that their children should learn to use computers. The *Parent's Guide to Computers in Education* has information parents can use to turn concern into effective action. This non-technical 80-page booklet:

- Shows why children should use and learn about computers,
- Explains how computers work,
- Describes ways students and teachers are using computers in schools and elsewhere,
- Suggests what parents can do,
- Provides a plan for buying a home computer, and
- Includes *Comes the Dawn* by Merle Marsh, a humorous account of one parent's entrance into the computer age.

QUANTITY	PRICE (U.S. FUNDS)
1-9 copies	$3.50 each
10-24 copies	$3.15 each
25-49 copies	$2.80 each
50-99 copies	$2.45 each
100+ copies	$2.10 each